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DERIVATION OF ANTHROPOMETRY BASED BODY FAT EQUATIONS FOR THE ARMY'S WEIGHT CONTROL PROGRAM

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

MAY 1988

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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Large inter-observer variability is a major disadvantage to the use of skinfold measurements for the prediction of percent body fat. This is particularly relevant in the Army's weight control program where standardized training is difficult for the large number of required observers located worldwide and who frequently turn over due to reassignment. This necessitated the development of an alternative method that required no formal training, could be administered by non-technical personnel and had low inter-observer variability. This report describes circumference-based equations that were developed to replace the skinfold equations. The equation selected for males was: % body fat = 46.892 - (68.678 x Log_{10} height) + (76.462 x Log_{10} (abdominal circumference - neck circumference)) with a R of 0.817 and a SEE of 4.020. The selected female equation was: % BF = -35.601 - (0.515 x height) + (0.173 x hip circumference) - (1.574 x forearm circumference) - (0.533 x neck circumference) - (0.200 x wrist circumference) + (105.328 x Log_{10} weight) with a R of 0.82 and SEE of 3.598. Height and circumferences are expressed in centimeters and weight in kilograms. The equations apply to all

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ages and racial groups. Conversion tables were developed for easy calculation of percent body fat from the raw measurements of circumferences, height and weight. In those individuals exceeding the weight-height table, the equation was more accurate in males in correctly classifying individuals than the weight-height table but only marginally better in women. Cross validation of the equations with an independent sample of Navy personnel resulted in a R of .89, a SEM of 3.7 and a mean difference with densitometry of 3.2% body fat units for men and a R of .79, SEM of 4.4 and a mean difference with densitometry of 0.2% body fat units for women. In addition to the ease of measurement by non-technical observers, the equations better predict % body fat measured by hydrostatic weighing than do the previously used Durnin-Womersley skinfold equations when considering all ages, racial groups and degrees of adiposity. (AU)

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DERIVATION OF ANTHROPOMETRY BASED BODY FAT EQUATIONS FOR THE ARMY'S WEIGHT CONTROL PROGRAM

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HUMAN RESEARCH

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

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FOREWORD

In 1982, the Exercise Physiology Division was tasked by the Army Surgeon General to conduct a major research study with which to revise the Army's Weight Control Program as described in Army Regulation 600-9. One major objective of this revision was to replace the skinfold caliper technique of estimating body fat with a method more appropriate to the Army's field applications. This report describes the development of the procedure that replaced the skinfold technique.

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ABSTRACT

Large inter-observer variability is a major disadvantage to the use of skinfold measurements for the prediction of percent body fat. This is particularly relevant in the Army's weight control program where standardized training is difficult for the large number of required observers located worldwide and who frequently turn over due to reassignment. This necessitated the development of an alternative method that required no formal training, could be administered by non-technical personnel and had low inter-observer variability. This report describes circumference-based equations that were developed to replace the skinfold equations. The equation selected for males was: % body fat = 46.892 - (68.678 x Log_{10} height) + (76.462 x Log_{10} (abdominal circumference - neck circumference)) with a R of 0.817 and a SEE of 4.020. The selected female equation was: % BF = -35.601 - (0.515 x height) + (0.173 x hip circumference) - (1.574 x forearm circumference) - (0.533 x neck circumference) - (0.200 x wrist circumference) + (105.328 x Log_{10} weight) with a R of 0.82 and SEE of 3.598. Height and circumferences are expressed in centimeters and weight in kilograms. The equations apply to all ages and racial groups. Conversion tables were developed for easy calculation of percent body fat from the raw measurements of circumferences, height and weight. In those individuals exceeding the weight-height table, the equation was more accurate in males in correctly classifying individuals than the weight-height table but only marginally better in women. Cross validation of the equations with an independent sample of Navy personnel resulted in a R of .89, a SEM of 3.7 and a mean difference with densitometry of 3.2% body fat units for men and a R of .79, SEM of 4.4 and a mean difference with densitometry of 0.2% body fat units for women. In addition to the ease of measurement by non-technical observers, the equations better predict % body fat measured by hydrostatic weighing than do the previously used Durnin-Womersley skinfold equations when considering all ages, racial groups and degrees of adiposity.

I INTRODUCTION

For a number of years the US Army has implemented a weight control program to promote physical readiness, good military appearance and health. Prior to 1982 this program, as published in Army Regulation 600-9, included only maximum weight for height as the standard for retention in the Army. However, physicians were allowed to waive the weight standards if a soldier appeared to be overweight due to an unusually muscular build. Some Army physicians used informally developed body composition criteria to make this determination. As the understanding of the distinction between excess fat and excess muscle mass improved (1), the Department of Defense directed the military services to develop and implement body fat methods and standards. These standards were to be the sole criteria for determining a service member to be overweight(2).

The Army Surgeon General convened a meeting on 17 Sep 1982 to develop a response to this Directive. An expert panel recommended the selection of the Durnin-Womersley (D-W) procedure for estimating body fat with age and gender adjusted equations employing four skinfold sites (bicep, tricep, subscapular and suprailiac)(3). The reasons for selection of these equations, which were developed in Great Britain as opposed to the many that have been developed in the United States, were the wide acceptance of the D-W procedure and its past extensive use and existing data base in US Army populations (4). It was recognized from the first that the equations and the body fat standards themselves would need validation in an Army population.

The revised Army Regulation (AR 600-9) issued in April 1983 incorporated body fat standards and the D-W skinfold procedure. The body fat standard and body fat assessment were applied when a service member exceeded the allowable weight for height standard or when his/her appearance, job performance or fitness test suggested excess body fat. In such cases the service member was referred by his/her unit to a Medical Department Activity (MEDDAC) for the skinfold measurement. The procedure was administered by an officer who had been credentialed to perform the measurement. These officers were usually dieticians and physical therapists.

The credentialing process consisted of training a small core group of personnel to perform the procedure under rigid standards of uniformity, reproducibility and conformity to one individual who had been calibrated against the "gold standard" of hydrostatic weighing. This training process was led by a co-author of this report (PIF), then the principle investigator for the Army's body composition research effort. This credentialed group then, in turn, credentialed others throughout CONUS and OCONUS until there were qualified individuals (referred hereafter as observers) in all MEDDACs. The original core group, as well as those trained by the principal investigator, served as "Caliper User Monitors" who validated measurements done by more junior observers. Despite these attempts at quality control in the execution of the skinfold measurements, it soon became evident that there was a great deal of variability between observers and considerable range in the quality of the measurements. Moreover, serial estimates of body fat in the same individuals frequently showed little or no changes despite significant losses of weight and equally significant improvements in fitness. It also became evident that the work load on MEDDAC personnel was considerable. A consensus developed in the Army Surgeon General's Office (OTSG) to conduct the validation study previously mentioned and to use the study results to develop an alternative technique for body fat estimation that was less susceptible to inter-observer variability and that could be performed by non-professional personnel, ideally, at the unit level. This resulted in a new tasking on 7 Mar 1983 from OTSG to the Exercise Physiology Division of this Institute to "develop an improved predictive equation based on skinfolds, body circumferences, and/or other anthropometric measurements which will allow more accurate estimates of body fat." This tasking was later clarified by the Consultants Division-OTSG to be a method at least as accurate as the D-W skinfold equation, but more consistent and reproducible between measurers, and to include only easily performed anthropometric measures. This report describes the approach, data collected and utilized and the process of deriving the final equations that were accepted by OTSG and the Army Chief of Staff and incorporated into a newly revised AR 600-9 implemented on 1 Oct 1986.

II BACKGROUND

A truism which the Army had to recognize in the development of the Weight Control Program is that actual measurement of body composition cannot be performed in a living human being. All methods which can be applied to live soldiers produce estimates of body composition which cannot be truly validated. The quality of the estimate depends on the elaborateness and expense of the methodology. Moreover, "validation" of a field methodology actually consists of comparisons with a more elaborate "laboratory" method.

The two laboratory methods most frequently used as "gold standards" are radioactive potassium counting and hydrostatic weighing (also called densitometry). Both are too time consuming and demanding of space, personnel and equipment to be used for field or large population testing as is needed for the Army Weight Control Program.

Densitometry, although widely used as a reference standard especially by those lacking access to a total body radioactive isotope counting chamber, has considerable limitations. Fundamentally, one uses a single equation, the Siri formula (21) to convert density to an estimate of body composition. This formula was based on a few autopsies and is the same regardless of age, race, gender or other factors which influence bone density. Further inaccuracies can enter from either the nomogram estimation or the measurement of the subject's residual lung volume. Densitometry also requires a degree of cooperation from the subject which may be difficult to achieve for cultural as well as personal reasons. Lastly, hydrostatic weighing is susceptible to deliberate cheating by a knowledgeable subject.

The Army is not alone in seeking convenient, accurate field methods for estimating body composition. A similar situation exists in a number of civilian applications (doctor's office, school, fitness center, epidemiology research). One answer to this problem has been the use of anthropometric variables to estimate body fat.

The earliest anthropometric approach was the use of simple weight-height indices (5,6) such as body mass index (BMI) (also referred to as Quetelet index) (weight/height^2) or Ponderal Index (weight $^{1/3}$/height). The correlation between BMI and % body fat is about 0.70 (7,8). The major deficiency of BMI is its inability to distinguish between over-fatness and over-muscularity. Attempts to better differentiate between fat and muscle mass with field expedient methods led to the use of skinfolds and circumferences. Skinfolds have been particularly popular as a predictive method due to the fact that a large proportion of fat is deposited in the subcutaneous layer which can be quantified with calipers (9).

The first skinfold prediction equations for body fat were developed for specific populations using combinations of several skinfold sites (1). These equations exhibit a higher correlation (about 0.85) and lower standard error of estimate than the BMI. These population specific equations were found to be affected by differences in age, gender and degree of fatness (10) and did not follow a linear relation with hydrostatically determined density (11). These problems led to the next step, the development of generalized, non-population-specific equations.

Durnin and Womersley (3) first reported such an attempt at equations that could be used over a broad population and take into account differences in age. This was followed by further refinements in the generalized equation approach reported by Jackson and Pollock (12,13). The advantage of these equations using skinfolds is that they are valid over a wide range of subjects and better account for differences in age, degree of fatness and the non-linearity between density and subcutaneous fat. The D-W equations were selected by the Army when it first implemented a body fat component into its weight control program in 1982.

Experience with the use of the D-W equations uncovered a variety of problems. Since the equations were developed in a population which was homogeneous as regards race and not particularly active physically, theoretical objections arose to their use in a racially diverse, physically active population. As previously described, the technique did not recognize obvious changes in body composition when performed serially on subjects who were complying with dietary and exercise directions. Lastly, since the D-W tables treat age as a group variable (ie., 16-29, 30-39, etc.) the subject's body fat estimate changes markedly between age groups. For example, a 49 year old woman with a sum of four skinfolds of 60 mm would carry an estimated body fat of 33.2% (and be considered under the Army Regulation as "not over weight"). On her fiftieth birthday, despite no change in weight or skin folds, the body fat estimate jumps to 35.7% and the individual suddenly becomes "overweight" under the regulation. A few such experiences by senior personnel served to fatally injure the credibility of the D-W method.

These problems, and especially the high inter- and intra-observer error with skinfold measurements (14,15) in the Army's widely dispersed setting, finally led to the conclusion that an alternative method must be found. The US Marine Corps and US Navy had earlier demonstrated that this problem could be solved as evidenced by their development and adoption of circumference-based equations (16,16a,17,18).

III APPROACH

In the course of discussion aimed at clarification and interpretation of the tasking, the following criteria were developed as desirable features of any new system:

a) contains no skinfold measurements

b) emphasizes circumference measures at easily locatable anatomic sites

c) not to exceed 4 measurements(excluding height and weight)

d) able to be executed by non-technically trained personnel

e) does not require elaborate or unavailable equipment

f) common equation for all race/ethnic groups

g) measurements should be avoided that require undressing beyond the Army sport ensemble

h) selected equations must have a correlation coefficient of at least .80 with hydrostatically determined percent body fat, and a standard error of the estimate not greater than 4.0 % body fat

i) equations should give comparable results in the three major race/ethnic groups

The following decisions were then made upon which the study design was developed:

a) hydrostatic weighing using direct measurement of residual lung volume would be used as the standard from which prediction equations would be developed

b) measurements would be gathered on a large sample of soldiers so that all age, gender and racial groups would be represented as well as a wide spread in occupations, time in service and degrees of fatness/leanness

c) a wide variety of candidate anthropometric measurements would be gathered

IV DESIGN

Based on these criteria, a study was carried out at Fort Hood, TX and Carlisle Barracks, PA on 1194 males and 319 females between 25 Jun and 1 Nov 1984. Table 1 describes the makeup of the sample by gender, age and race. Further description of the sample and the data collection process can be found in an earlier report(23).

In addition to hydrostatic weighing to determine body density for the computation of percent body fat, a number of anthropometric measures were collected as candidate predictors as listed in Table 1a.

V METHODS

A Hydrostatic weighing

Hydrostatic weighing for the determination of body density was carried out with the use of a 4 ft. wide x 4 ft. long x 5 ft. deep aluminum tank constructed in our laboratory (19). An aluminum chair was coupled with an electronic load cell transducer (Ametek model 6000), sensitive to 10 grams, and both were suspended from a stainless steel bar mounted over the top of the tank. Output from the load cell was fed through an analog-to-digital converter (Hewlett-Packard model 59313A) to a desk top computer (Hewlett Packard model 85), programmed to store values for subsequent determinations of a stable underwater weight and body composition parameters.

The weighing procedure was similar to that described by Goldman and Buskirk (20). Subjects reported in nylon swim suits. After they were weighed in air and completed the residual lung volume measurement(see below), they entered the tank. Water temperature was maintained between 34 and 39 degrees C by a heater located in the circulating pump and filter system which operated between subject weighings. After careful familiarization of the subject with the equipment and procedures, the weight of the seat, snorkel apparatus and an 8 kg weighted diving belt was determined with the subject submerged up to the neck. Submersion was necessary because the water level in the tank rises as a person becomes submerged which affects the final weight of the seat. The subject then sat in the seat wearing the belt, attached a noseclip and breathed through a mouthpiece attached to snorkel apparatus. Weighings were then made during successive trials with the subject submerged and bending forward at the waist and maximally exhaling and holding his breath until stable weight readings were established. A series of 7 to 10 trials were made. Body density (grams per cubic centimeter) was converted to percent body fat using the formula of Siri (21). Further details can be found in an earlier report (10). Of the total sample, 121 subjects (68 males and 53 females) had to be excluded from the data analysis due to their inability to successfully complete the hydrostatic weighing procedure due to fear of being submerged in water (referred here to as hydrophobia). This group of 121 accounts for the difference in sample sizes between Table 1 and Table 2.

In a separate study (19) prior to commencing measurements in this project, repeated measures were made on 35 subjects with the same equipment and procedures to assess variation between days and trials. Twenty-six men and nine women were weighed 10 times in succession each day for five successive days. No statistically significant changes in density over days or within trials (days $F=0.29$, trials $F=0.78$, day/trial $F=0.64$) were found.

B Residual Lung Volume

An accurate determination of an individual's density from underwater weight for the subsequent determination of body fat requires that residual lung volume be measured just prior to or during the underwater weighing process. In this study residual lung volume was determined just prior to the actual hydrostatic weighing process with the subject outside of the weighing tank. A simplified oxygen rebreathing technique was utilized (22). The subject assumed a sitting position similar to the posture utilized in the underwater weighing procedure. With a nose clip in place, the subject breathed through a mouthpiece and a 'T' valve opened to room air. The subject then performed a maximal expiration to the point of residual volume at which point the 'T' valve was opened to a five liter bag of 100% oxygen. The subject then took 5-7 deep breaths at a uniform rate (one breath every two seconds). Following the inhalation of the oxygen, the subject then exhaled maximally and the valve was turned to close off the bag and return to room air. The contents of the bag were mixed and analyzed for oxygen and carbon dioxide. Residual volume was calculated as:

$RV = (VO_2 \times \%N_2) - (79.8 - \%N_2)$ where $\%N_2$ is found as $100\% - (\%O_2 + \%CO_2)$. If there was greater than 150 ml difference between two measurements, a third was taken, and the two closest values were averaged.

C Anthropometry

All anthropometric measurements were made using standardized techniques described by Behnke and Wilmore (1). Measurements were taken on the right side of the body with the subject wearing shorts and a T-shirt. A total of 9 diameters and 14 circumferences as listed in Table 1a were measured on each subject. Specific descriptions of the anatomic locations of these sites as well as the determination of height and weight are found in the article by Behnke and Wilmore (1) and also in Appendix A to this report.

VI EQUATION DEVELOPMENT

The following approach was used to arrive at the new body fat prediction equations:

a) A simple correlation matrix was constructed of all the measured variables to identify individual measures which had a high correlation with % body fat, and to identify variables that were highly intercorrelated.

b) A number of derived variables, combinations of variables and log transformations were added to the variables examined.

c) These combinations were selected sums, differences, and ratios which the experience of the investigators suggested might be effective predictors of body composition. Ease of explanation to the lay user was also a factor in developing derived variables.

d) The capabilities of the BMDP family of statistical programs were used to vary the weighting and order of variables entering the equations.

e) Step-wise regressions were performed for male and female data separately, looking for combinations of variables that produced equations that met the established criteria.

f) Approximately 35 equations were derived and examined against the desirability criteria previously discussed.

g) Based on all stated criteria and restrictions, two equations were selected as optimum for the Army's purposes.

VII RESULTS

Table 2 describes the makeup of the subject population by age and race after hydrophobics were removed from the original sample. It should be noted that the female sample had a high percentage of Blacks, 38% as opposed to 28% for males. Approximately half of the male sample was 28 years old or over while only 22% of the women in the sample were over 28 years.

Tables 2 and 3 present the characteristics (mean $\pm$ SD) of the sample by race and age groups. A more detailed presentation of these data are presented in an earlier report (23). Of particular note is the fact that the Black male sample has a higher body density, larger fat free mass and lower % body fat on the average than the male White or Hispanic sample. This trend is much less evident in females. There is a noticeable and expected trend for density to decrease and % body fat to increase with increasing age in both genders.

The equations which met our criteria and were chosen for implementation are listed in Table 4. A description of the circumference measuring procedures and the body fat calculation tables developed for AR 600-9 (Army Weight Control Program) are presented in Appendix A.

The male equation was developed from the combined sample of all racial and all age groups. A problem encountered in developing the female equation was the difficulty in predicting density in Black women. Consistently, correlation coefficients were lower and standard error of the estimate larger in this group than in White or Hispanic women. The female equation selected was developed from the White-all age sample since the equations developed from the combined racial sample did not reach the desired .80 correlation coefficient level. Table 5 presents the correlation coefficients and SEE when the selected variables are applied to each racial group. The discrepancy in the predictive power of the equation between Blacks and Whites is particularly evident in women.

Figure 1a depicts the relationship in the total male sample between the circumference-derived % body fat and that from hydrostatic densitometry. This is contrasted in Figure 1b with the D-W skinfold versus hydrostatic densitometry relationship. The same relationships for the total female sample are illustrated in Figures 2a and 2b. Both circumference and D-W skinfold equations tend to over-predict % body fat (as estimated by densitometry) in lean individuals and under-predict in obese individuals. This trend for under-prediction at the upper end of the body fat scale is less for the circumference equation, i.e., its regression line slope is closer to the line of identity. Regression lines for the two types of equations for the female sample are nearly identical. Table 6 compares the mean values derived from the two equations and hydrostatic densitometry by gender, age group, racial group and relative adiposity as represented by BMI. These comparisons are also illustrated in Figures 3 - 5.

A further evaluation of the developed equations is illustrated in Table 7. In this analyses, the accuracy of the equations against hydrostatic weighing is contrasted in those male subjects below 18% body fat and those male subjects above 18% body fat and similarly for female subjects below and above 28% body fat. The results (Table 7) show that the equations are more accurate (higher correlation coefficient) in the higher fat group than the leaner group as one would desire since the equations are only used in over-weight individuals.

The final evaluation of these equations is specific to their application in the weight control program and is shown in Tables 8 and 9. In the male subjects in this study, 25.8% exceeded the weight-height tables. When comparing these subjects weight-height met/exceeded rating against the current body fat standard, the weight-height tables correctly classified 66.6% of the population as over-fat, i.e., 66.6% exceeded the fat standard and thus were in agreement with the weight-height table. When this group was compared with the body fat standard using the circumference equations (as opposed to the weight-height tables), 77.3% were correctly classified. Thus in males, the equations increased the accuracy of correctly classifying overweight individuals from 66.6% to 77.3%.

Such an improvement in accuracy was not seen in females (Table 9). Of the 35.1% of the total female sample who exceeded the weight table, 67.0% were correctly classified by the weight-height table. Correct classification by the equation was only slightly better, 69.1%.

VIII EQUATION VALIDATION

Upon completion of the development of these equations, we were given the opportunity to validate them against a large independent sample composed of U.S. Navy active duty personnel. This sample had also been used to develop predictive equations for the Navy (17,18) and had been hydrostatically weighed for body density by procedures similar to ours. Characteristics of this sample are given in Table 10.

By referring back to Table 2, it can be seen that the Navy male sample was older (1.7 yrs.), taller (2.5 cm), heavier (8.4 kg) and had a slightly higher % body fat (21.5 vs. 20.6). The female samples were more comparable.

Table 11 presents a statistical comparison of % body fat by paired t test between that derived from the circumference equations and that from hydrostatic densitometry. These results show that, on the average, our equation agreed well with densitometry in this independent sample of females but did less well in the sample of males - a mean difference of 3.2 body fat percentage units. Table 12 offers data which elaborate on these comparisons. This table presents the relative occurrence of over, under and correct prediction as a function of adiposity. It can be seen that in the male sample, 458 out of the total sample of 997, or 45.9% were overpredicted 3.2 percentage units or more by the equation. Of this portion, slightly over half fall into the lean category. Thus, our male equation has a noticeable tendency to overpredict % body fat in lean individuals in this sample. The extent of underprediction was very low (3.1 % of total). The Navy has also experienced overprediction in lean individuals using their equations (17). Our equation gave a similar degree of underprediction (21.4 %) and overprediction (16.9 %) in the female sample.

IX DISCUSSION AND SUMMARY

The objectives of this project were to develop a procedure of estimating percent body fat for the Army's Weight Control Program that could be used within a unit by non-technically trained personnel and would have less inter-observer variability while still yielding comparable accuracy with the early skinfold procedure. All of these objectives appear to have been met. The equations require only the measurement of height, body weight and 2-4 body segment circumferences with a tape measure. Even though the equations include logarithmic transformation, simple calculation tables have been constructed so that all measurements and computations can readily be performed in the "field" by non-technical personnel. Prior to release of the revised Army Regulation, field testing was used to demonstrate that the technique could be learned and applied consistently by junior enlisted soldiers with no medical training. Required training time for the circumference technique is considerably less than for the skinfold procedure. In unpublished data from this laboratory (24) using Master Fitness Trainees as measurers, there was no significant difference within repeated measurements on men ($P>.30$) or women ($P>.65$) or between measurers ($P>.70$), confirming our original hypothesis that the circumference technique would be more reproducible than the skinfold technique.

As mentioned earlier, numerous candidate equations were developed and examined using single, combined, derived and log transformed variables. The primary reasons for rejecting equations were: an excessive number of required measurements or too low predictive power (low correlation coefficient and high standard error of estimate). A key factor in evaluating candidate equations was their ability to predict body fat accurately in all the major racial subgroups.

These new Army equations are as accurate as other previously published generalized equations (12,13) and the Navy equations (17,18). They are actually superior to the previously used D-W equations in several respects. In males, there is less underprediction of fat individuals as with the D-W skinfold procedure and a higher overall correlation coefficient and an absolute mean value closer to densitometry across age and racial groups. For females, the correlation coefficient was again higher for the circumference equations as compared to the skinfold equations although mean values across age and racial groups were variable.

An important test of the adequacy of derived prediction equations is their application in an independent sample, separate from the population from which they were derived. An active duty Navy population was used for this purpose and demonstrated acceptable correlation coefficients (.89 and .79, male and female respectively) and low standard error of measurements.

We also evaluated the relative accuracy of the new equations as to how well they specifically performed in over-weight or over-fat individuals as they are employed in the Army's Weight Control Program. This was carried out by evaluating the equation against densitometry across body mass index groups, across body fat groups and in those exceeding the weight-height table. The equations agreed with densitometry as well or better in the higher body mass index groups (Table 6) and performed better in the high body fat versus low body fat group in both genders (Table 7). In those individuals exceeding the weight-height table, the equation was more accurate in males in correctly classifying individuals than the weight-height table but only marginally better in women (Table 8 and 9).

Taking into account the limitations and conditions that exist in the Army's program to screen for body fat, it is concluded that these new circumference based equations are superior to the previous D-W skinfold equations in both practical and technical terms. The circumference procedure nevertheless suffers from the same limitations as all indirect anthropometry derived procedures and still fails to accurately estimate body fat in a limited number of cases. Thus, this method is not foolproof but rather is a screening tool to help the unit commander differentiate between over fatness and over muscularity. The equations, as presented in this report, were approved by the Army Surgeon General, the Deputy Chief of Staff for Personnel and the Chief of Staff of the Army for incorporation into the Army's Weight Control Program. Their inclusion into Army Regulation 600-9 is as shown in Appendix A to this report.

After the issuance of the computation tables for the circumference technique in AR 600-9 (as shown in Appendix A of this report), a discrepancy was found for males between using the equation and using the computation tables. This occurred when converting from metric units in the equation to inches in the tables. This resulted in a constant 3.15% underestimation of percent body fat by the table. This error occurred only with the male table; the female table being correct as issued. A corrected male computation table is found in Appendix B to this report. This corrected table will be issued in the next revision of AR 600-9. Such a revision is currently under consideration due to a recent revision in the Department of Defense Directive (calling for a body fat standard) which now calls for a more stringent standard in the methodology.

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Table 1. Age and racial distributions of original subject population (frequency and percent of sample).

Age Group		White	Black	Hispanic	Other	Total
		- MALES -				
17-20	n	102	43	17	4	166
	%	7	4	1	1	14
21-27	n	209	133	51	13	406
	%	18	11	4	1	34
28-39	n	174	95	60	19	348
	%	15	8	5	2	29
40 >	n	238	17	11	8	274
	%	20	1	1	1	23
All	n	723	288	139	44	1194
	%	61	24	12	4	100
		- FEMALES -				
17-20	n	41	20	8	3	72
	%	13	6	3	1	23
21-27	n	84	79	12	4	179
	%	26	25	4	1	56
28-39	n	37	23	4	2	66
	%	12	7	1	1	21
40 >	n	2	0	0	0	2
	%	1				1
All	n	164	122	24	9	319
	%	51	38	8	3	100

Table 1a. Anthropometric measures collected as candidate predictors.

Circumferences	Diameters	Other
head	biacromial	body weight
neck	chest	height
bicep, relaxed	biilac	
bicep, flexed	deltoid	
shoulder	bitrochanter	
chest	elbow	
abdominal-1	wrist	
abdominal-2	knee	
hip	ankle	
forearm		
wrist		
thigh		
calf		
ankle		

Table 2. Subject characteristics by racial group after hydrophobics were removed. Mean±SD. (FF = fat free).

Variable	White	Black	Hispanic	All
		- MALE -		
n	696	253	134	1126
Age	31.6 ± 9.7	26.9 ± 6.5	28.7 ± 7.0	30.2 ± 8.9
Height, cm	176.4 ± 6.8	174.4 ± 6.5	171.2 ± 6.0	175.0 ± 6.9
Weight, kg	78.3 ± 11.0	76.0 ± 11.3	74.7 ± 11.4	77.1 ±11.3
Density/g/cc	1.049 ± .014	1.062 ± .016	1.050 ± .015	1.052 ±.016
Body fat, %	22.0 ± 6.3	16.1± 7.1	21.7 ± 6.7	20.6 ± 7.0
F F Mass, kg	60.6 ± 7.0	63.2 ± 7.4	58.1 ± 6.9	60.8 ± 7.3
		- FEMALE -		
n	147	93	18	266
Age	24.3 ± 5.1	23.9 ± 3.6	23.1 ± 3.8	24.1 ± 4.5
Height, cm	163.0 ± 6.1	163.0 ± 6.2	158.5 ± 6.2	162.6 ± 6.2
Weight, kg	60.7 ± 8.2	60.5 ± 8.1	58.8 ± 7.3	60.4 ± 8.2
Density, g/cc	1.035 ± .013	1.038 ± .0 13	1.036 ± .011	1.036 ±.013
Body fat, %	28.5 ± 6.2	27.1 ± 5.9	28.4 ± 5.1	28.0 ± 6.1
F F Mass, kg	43.1 ± 4.7	44.0 ± 5.2	41.9 ± 4.1	43.3 ± 4.9

Table 3. Subject characteristics by age groups (Mean±SD).

Variable	17-20	21-27	28-39	40>	All
			- MALES -		
n	162	389	318	259	1128
Height,cm	174.7 ± 5.9	174.0 ± 6.8	174.3 ± 7.3	177.8 ± 6.6	175.0±6.9
Weight,kg	72.9 ± 8.7	74.2 ±10.6	79.4 ±12.9	81.2 ± 9.5	77.1±11.3
Density, g/cc	1.061 ±.0131	.058 ± .015	1.047 ± .016	1.044 ±.011	1.052±.016
Body fat, %	16.6 ± 5.8	18.0 ± 6.5	22.9 ± 7.0	24.2 ± 5.2	20.6 ±7.0
F F Mass,kg	60.6 ± 6.4	60.5 ± 7.4	60.7 ± 8.2	61.3 ± 6.6	60.8 ± 7.3
			- FEMALES -		
n	62	155	52	2	171
Height,cm	162.1 ± 6.2	162.4 ± 6.4	163.6 ± 5.8	157.3 ± 4.2	162.6±6.2
Weight, kg	59.9 ± 7.7	59.5 ± 8.1	63.6 ± 8.4	59.0 ± 6.7	60.4±8.2
Density, g/cc	1.036 ± .011	1.038 ± .013	1.030 ±.015	1.025 ±.022	1.036±.013
Body fat, %	27.9 ± 5.2	27.0 ± 5.9	30.5 ± 6.7	32.9 ±10.2	28.0±6.1
F F Mass,kg	43.2 ± 4.6	43.1 ± 5.0	44.0 ± 5.0	39.3 ± 1.5	43.3±4.9

Table 4. Equations selected for implementation in the revision of the Army's Weight Control Program. Height and circumferences are expressed in centimeters, weight in kilograms.

Male:
$\%\ BF = 46.892 - (68.678 \times \log_{10} \text{height}) + (76.462 \times \log_{10} (\text{abdominal-2 circumference} - \text{neck circumference}))$

R = 0.817 SEE = 4.020

Female:
$\%\ BF = -35.601 - (0.515 \times \text{height}) + (0.173 \times \text{hip circumference}) - (1.574 \times \text{forearm circumference}) - (0.533 \times \text{neck circumference}) - (0.200 \times \text{wrist circumference}) + (105.328 \times \log_{10} \text{weight})$

R = 0.820 SEE = 3.598

Table 5. Correlation coefficients and SEE for the selected equation variables (against hydrostatic weighing) when applied to separate racial groups.

	MALES		FEMALES	
	R	SEE	R	SEE
All	0.817	4.020	0.783	3.811
White	0.785	3.914	0.820	3.598
Black	0.824	4.012	0.734	4.076
Hispanic	0.802	4.027	0.853	3.332

Table 6. Comparison of computed percent body fat between densitometry, circumference procedure and skinfold procedure(D-W equations) as a function of gender, age, race and body mass index (BMI).

AGE	17-20	21-27	28-39	40+	All
MALES					
n=	161	389	318	258	1126
Densit.	16.5±5.8	18.0±6.5	22.9±7.0	24.2±5.2	20.6±7.0
Circum.	17.5±4.9	18.6±5.3	22.3±6.0	23.4±4.0	20.6±5.7
Skinfold	17.9±4.0	18.1±4.6	21.5±4.9	26.8±4.1	21.1±5.6
FEMALES					
n=	60	153	51	-	266
Densit.	27.9±5.2	27.0±5.9	30.5±6.7	-	28.0±6.1
Circum.	28.0±4.6	28.1±4.6	30.0±5.3	-	28.5±4.8
Skinfold	28.0±4.6	26.5±5.1	29.5±5.0	-	27.5±5.1

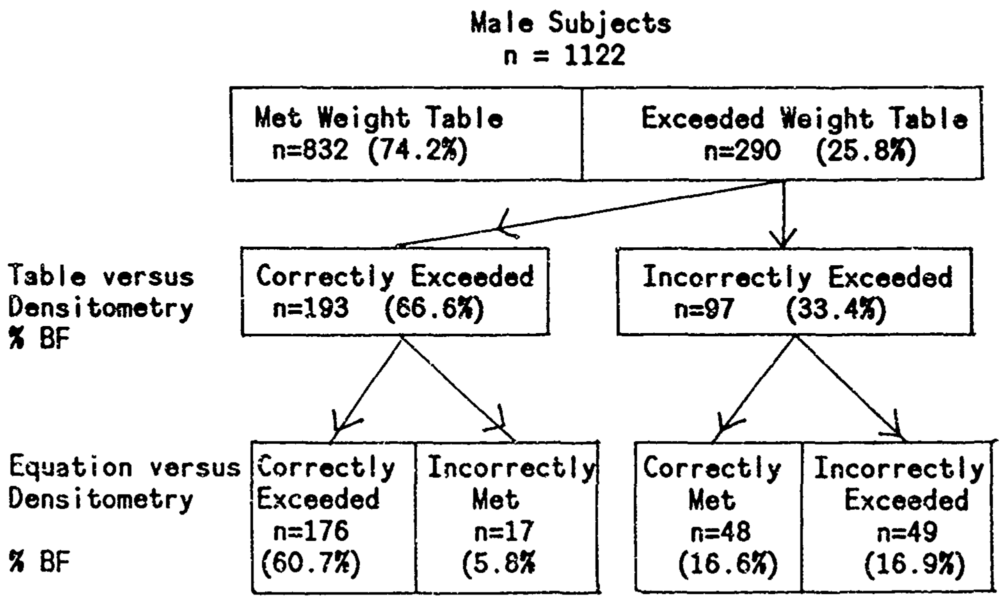
RACE	White	Black	Hispanic	All
MALES				
n=	696	253	134	1126
Densit.	22.0±6.3	16.1±7.1	21.7±6.7	20.6±7.0
Circum.	21.7±5.2	17.7±5.8	21.3±6.0	20.6±5.7
Skinfold	21.1±5.7	22.2±5.5	18.3±5.5	21.1±5.7
FEMALES				
n=	147	93	18	266
Densit.	28.5±6.2	27.1±5.8	28.4±5.1	28.0±6.1
Circum.	28.7±5.0	28.0±4.8	30.0±3.6	28.5±4.8
Skinfold	28.1±5.0	26.3±5.3	28.1±4.4	27.5±5.1

BMI	<22.9	22.9-24.9	25.0-26.9	>26.9
MALES				
n=	290	295	297	291
Densit.	15.1±5.3	18.7±5.6	22.5±5.9	26.3±5.5
Circum.	14.8±3.6	18.9±3.6	22.3±3.7	26.6±3.7
Skinfold	15.7±3.9	20.1±4.6	23.0±4.7	25.6±4.2
FEMALES				
n=	74	78	76	74
Densit.	23.4±5.5	26.3±4.1	29.0±4.2	33.3±5.7
Circum.	23.5±2.9	27.2±2.3	29.4±2.9	33.8±4.0
Skinfold	23.3±4.3	25.7±3.8	28.8±3.4	32.1±4.2

Table 7. Accuracy of the circumference equations by body fat grouping as expressed by correlation coefficients between densitometry derived percent body fat and circumference equation derived percent body fat.

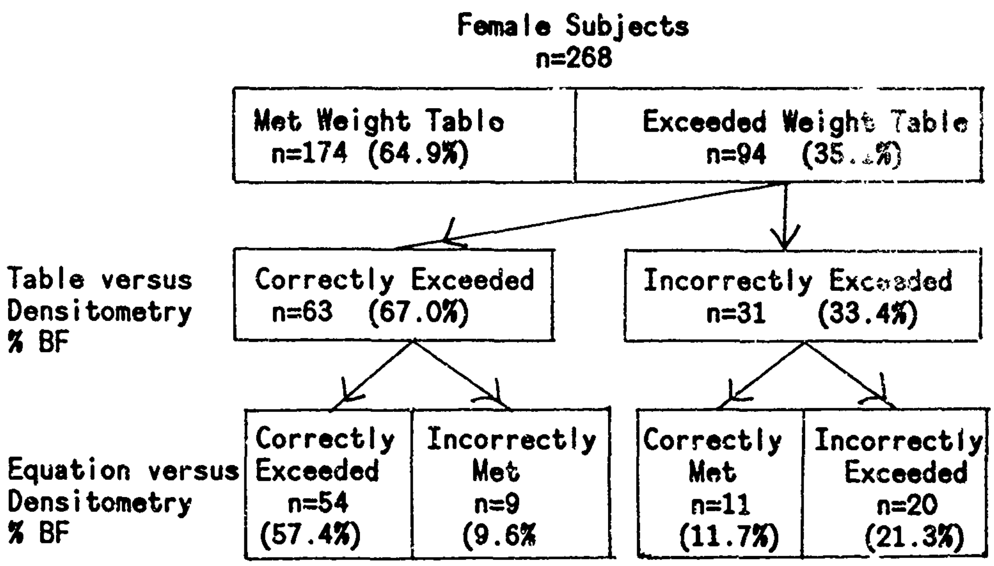
Body Fat Grouping	Correlation Coefficient Males	Females
All	.817	.820
Below 18%	.556	---
Above 18%	.658	---
Below 28%	---	.562
Above 28%	---	.659

Table 8. Circumference equation accuracy in those male subjects from this study exceeding the weight-height table.



Equation correct: 77.3%
Equation incorrect: 22.7%

Table 9. Circumference equation accuracy in those female subjects from this study exceeding the weight-height table.



Equation correct - 69.1%
Equation incorrect - 30.9%

Table 10. Subject characteristics of an independent Navy sample used for equation validation.

	Mean	SD	Range
Males n = 1003			
Age	31.9	6.9	17.0 - 56.0
Height, cm	177.5	7.0	154.9 -197.5
Weight, kg	85.5	14.5	50.5 -143.3
Density, gm/cc	1.050	.018	1.008 - 1.100
*Body fat, %	21.5	8.1	0.2 - 40.9
Females n = 348			
Age	26.6	5.2	18.0 - 48.0
Height, cm	164.3	6.8	148.0 - 186.7
Weight, kg	62.2	9.4	38.9 - 102.7
Density, gm/cc	1.038	0.015	.996 - 1.076
*Body fat, %	26.8	7.1	10.2 - 47.1

* Derived from densitometry

Table 11. Statistical comparison of % body fat values in independent Navy sample between circumference equations and hydrostatic densitometry.

	Mean % BF	SD	Mean Diff.	*SEM	R	P
		- Males -				
Densitometry	21.5	8.1	3.2	3.7	.89	<.001
Circumference Eq.	24.7	6.4				
		- Females -				
Densitometry	26.8	7.1	0.2	4.4	.79	>.1
Circumference Eq	26.6	4.9				

*Standard error of measurement.

Table 12. Summary of prediction accuracy in Navy sample by relative degrees of adiposity. 3.5% fat units represents approximately one standard error.

Males

	Adiposity Group*			
	Lean	Middle	Fat	Total
Under predicted	1	5	25	31
diff. >3.5% fat units	.1%	.5%	2.5%	3.1%
at prediction	73	186	249	508
	7.3	18.7%	25.0%	51.0%
over prediction	256	136	66	458
diff. >3.5% fat units	25.7%	13.6%	6.6%	45.9%
	330	327	340	997
Total	33.1%	32.8%	34.1%	100%

Females

	Lean	Middle	Fat	Total
Under predicted	1	21	50	72
diff. >3.5% fat units	.3%	6.2%	14.8%	21.4%
at prediction	63	88	57	208
	18.7%	26.1%	16.9%	61.7%
over prediction	52	4	1	57
diff. >3.5% fat units	15.4%	1.2%	.3%	16.9%
Total	116	113	108	337
	34.4%	33.5%	32.0%	100%

*Male lean: <18.1% BF — Female lean: <23.8% BF
Male middle: 18.1 - 25.4% BF — Female middle: 23.8 - 30.0% BF
Male fat: >25,4% BF — Female fat: >30.0% BF

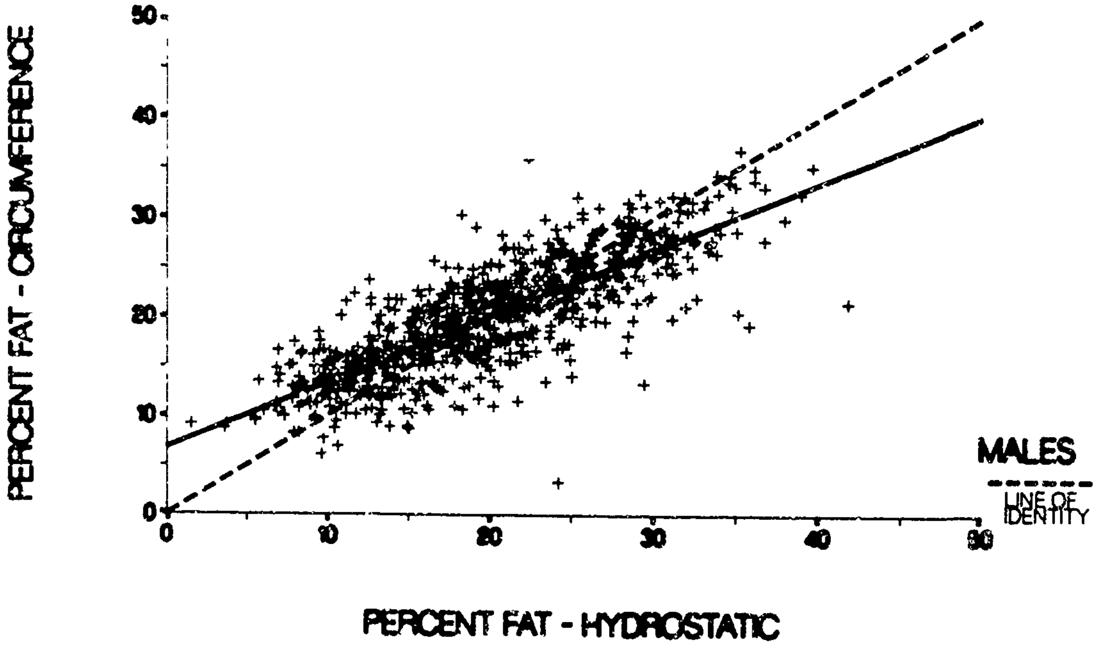


FIGURE 1a. Scatter plat and regression line for all males for % body fat by circumference equation plotted against % body fat from hydrostatic densitometry, R = .81.

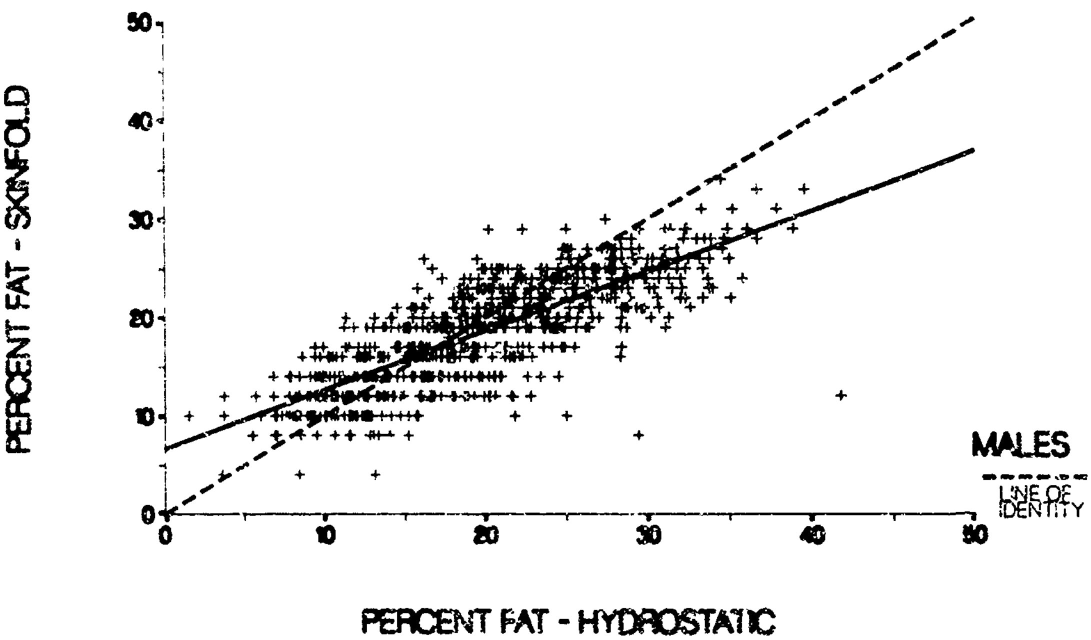


FIGURE 1b. Scatter plat and regression line for all males for % body fat by D - W skinfold equation platted against % body fat from hydrostatic densitometry, R = .78.

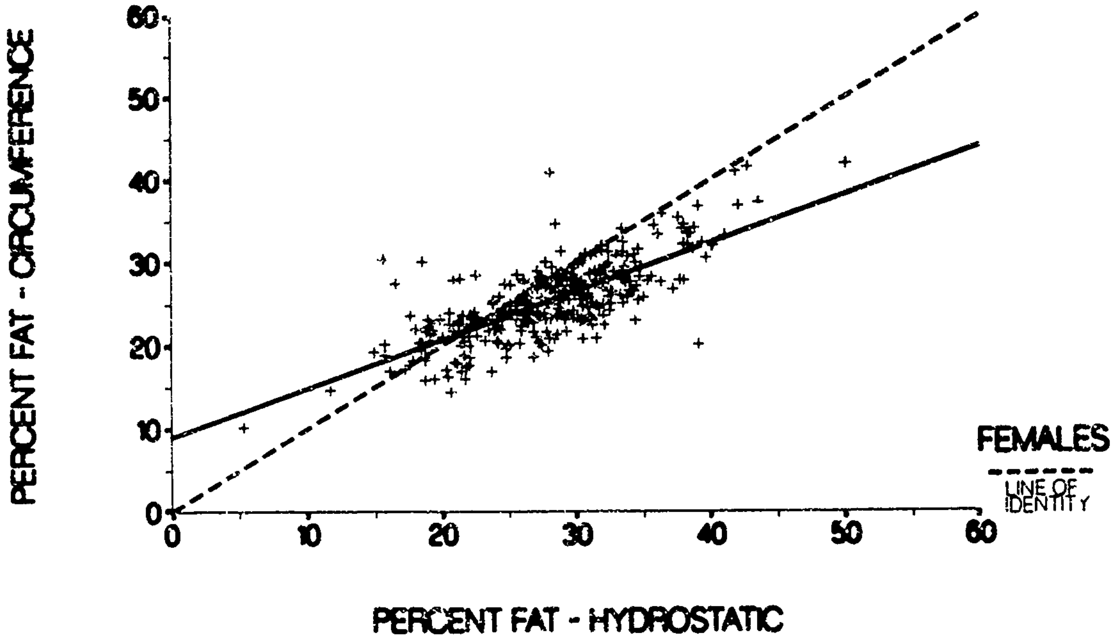


FIGURE 2a. Scatter plot and regression line for all females for % body fat by circumference equation plotted against % body fat from hydrostatic densitometry, R = .74.

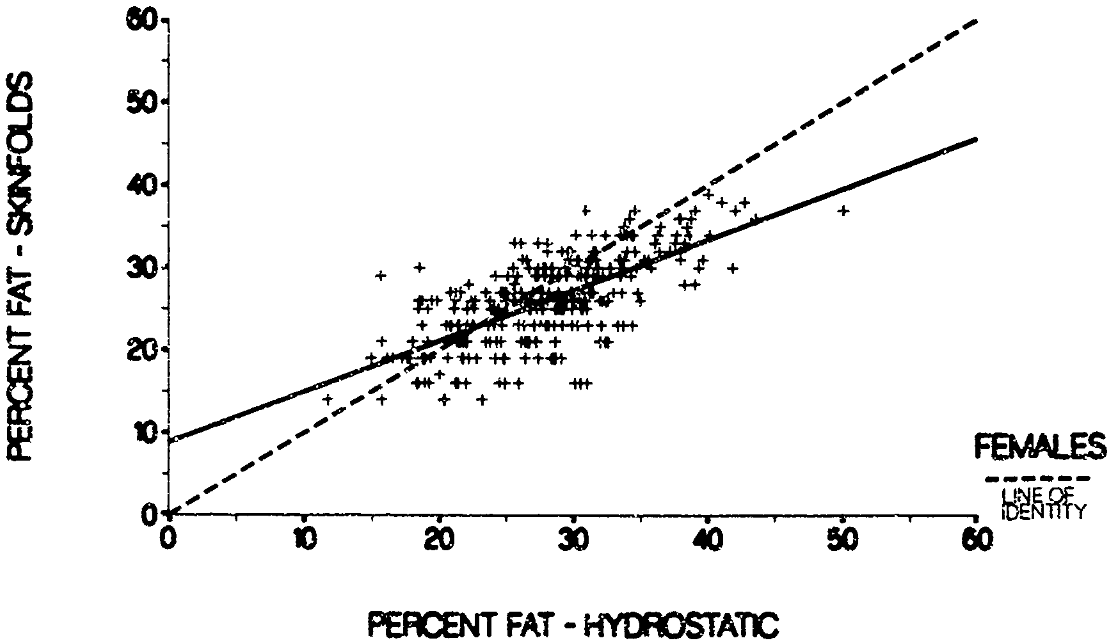


FIGURE 2b. Scatter plot and regression line for all females for % body fat by D - W skinfold equation plotted against % body fat from hydrostatic densitometry, R = .69.

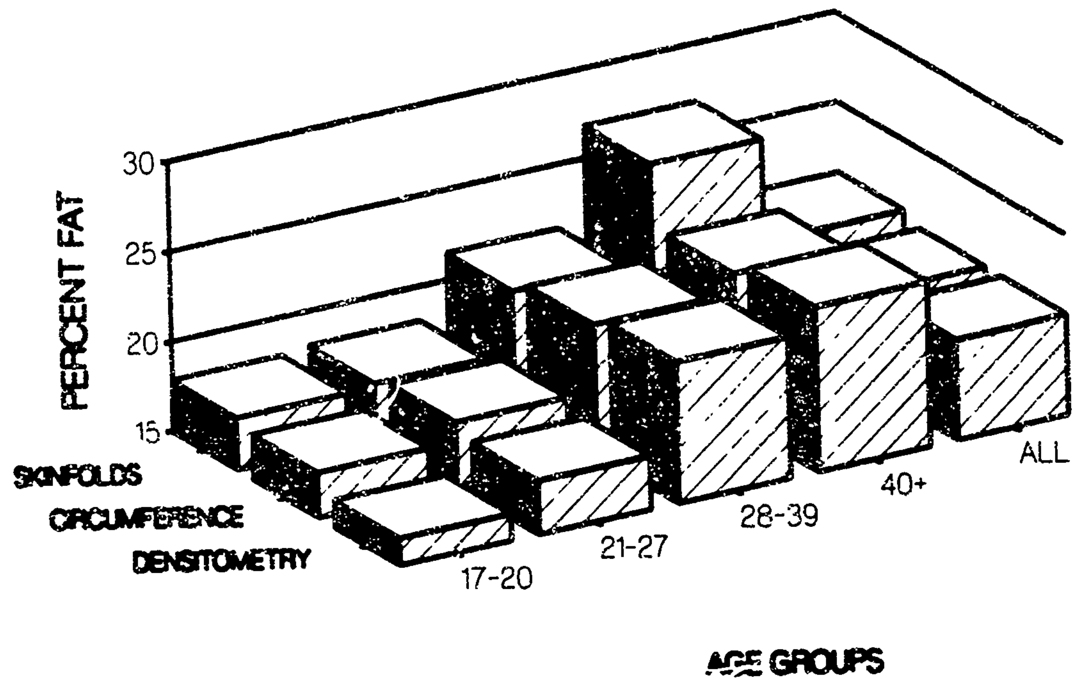


FIGURE 3a. Histogram comparing male group means of % body fat by three methods as a function of age groupings.

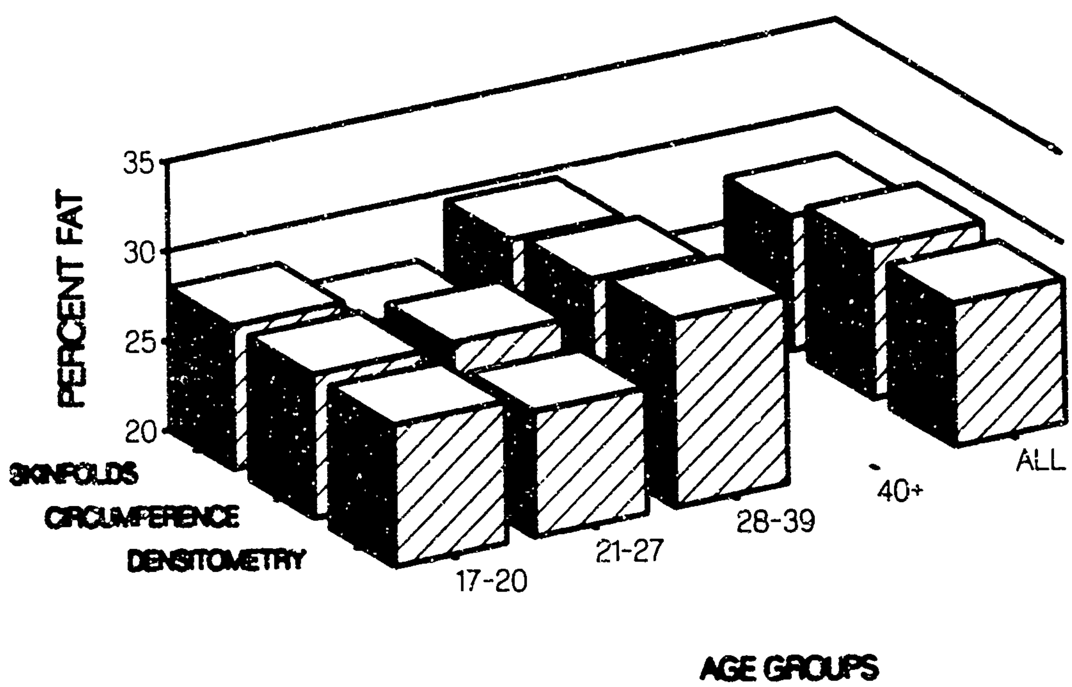


FIGURE 3B. Histogram comparing female group means of % body fat by three methods as a function of age groupings.

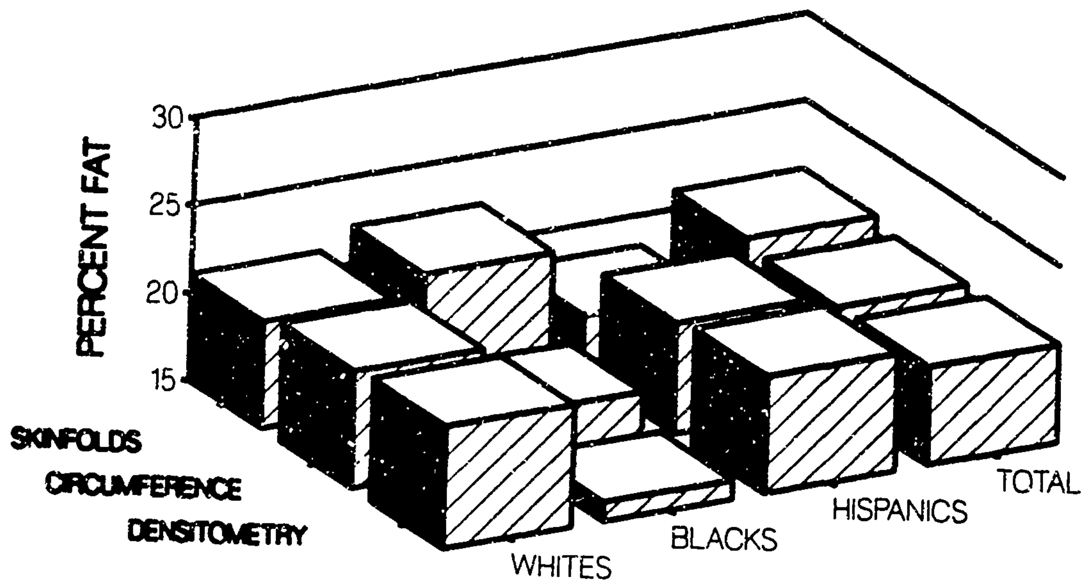


FIGURE 4a. Histogram comparing male group means of % body fat by three methods as a function of ethnicity.

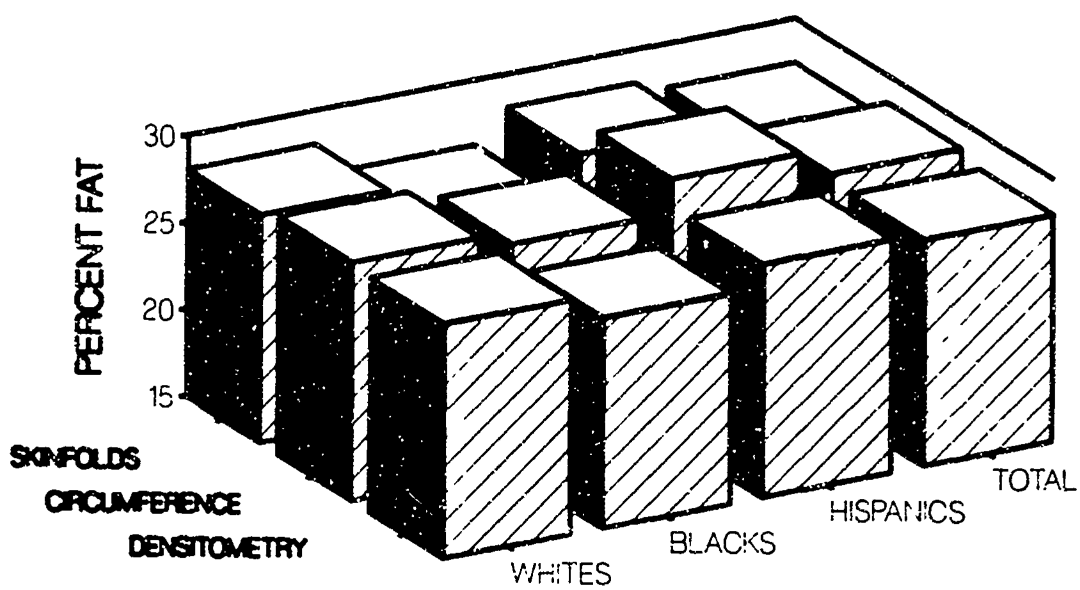


FIGURE 4b. Histogram comparing female group means of % body fat by three methods as a function of ethnicity.

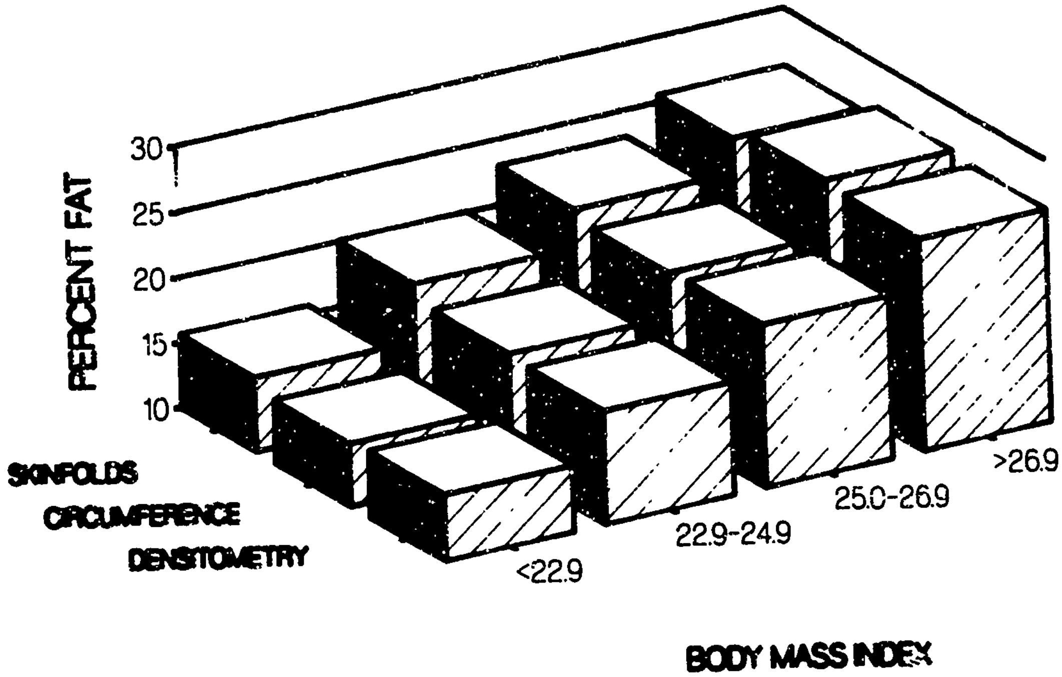


FIGURE 5a. Histogram comparing male group means of % body fat by three methods as a function of BMI groupings.

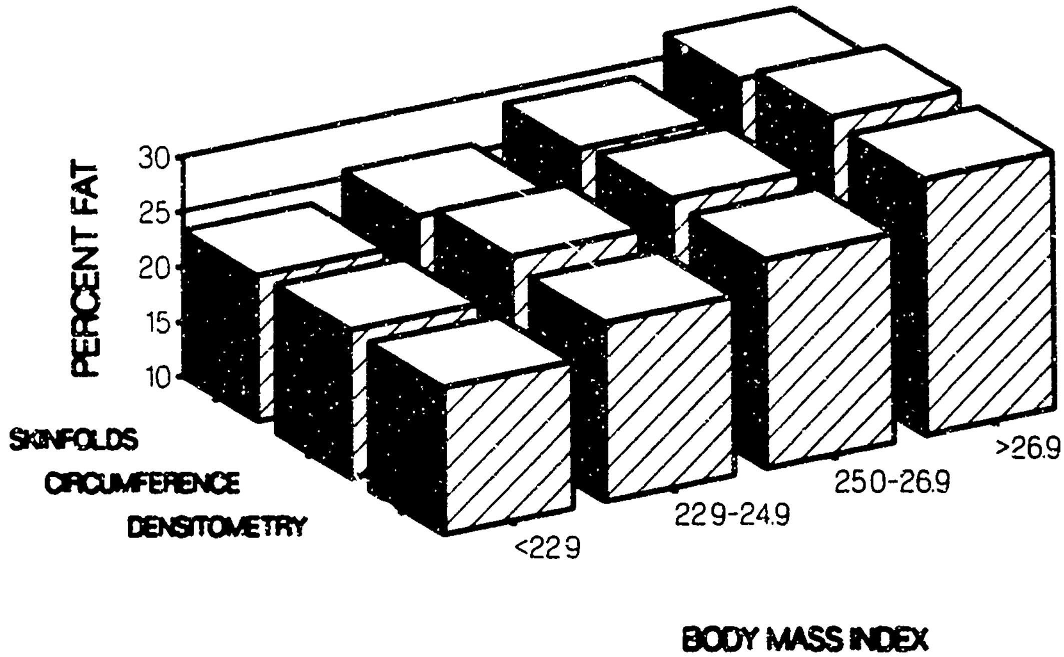


FIGURE 5b. Histogram comparing female group means of % body fat by three methods as a function of BMI groupings.

Appendix - A

This appendix describes the instructions developed for the implementation of the circumference based prediction equations. It includes specific directions for the measurements to be made plus conversion tables and calculation worksheets to convert the raw measurements into percent body fat values.

1. Introduction.

a. Measurements will be made three times. If there is greater than 1/4-inch difference between measurements, then continue measuring until you have three measurements within 1/4-inch of each other. An average of the scores that are within 1/4-inch of each other will be used.

b. When measuring circumferences, compression of the soft tissue is a problem that requires constant attention. The tape will be applied so that it makes contact with the skin and conforms to the body surface being measured. It should not compress the underlying soft tissues. Note, however, that for the hip circumference more firm pressure is needed to compress gym shorts. All measurements are made in the horizontal plane, (i.e., parallel to the floor), unless indicated otherwise.

c. The tape measure should be made of a non-stretchable material, preferably fiberglass, cloth or steel tapes are unacceptable. The tape should be 1/4- to 1/2-inch wide (not exceeding 1/2-inch) and a minimum of 5-6 feet in length. A retractable fiberglass tape is the best type for measuring all areas.

2. Height and weight measurements

a. The height will be measured with the soldier in stocking feet (without shoes) and standard PT uniform, i.e., gym shorts and T-shirt, standing on a flat surface with the head held horizontal, looking directly forward with the line of vision horizontal, and the chin parallel to the floor. The body should be straight but not rigid, similar to the position of attention. Unlike the screening table weight, this measurement will be recorded to the nearest 1/4-inch in order to gather a more accurate description of the soldier's physical characteristics.

b. The weight will be measured with the soldier in a standard PT uniform, i.e., gym shorts and a T-shirt. Shoes will not be worn. The measurement should be made on scales available in units and recorded to the nearest pound with the following guidelines:

(1) If the weight fraction of the soldier is less than 1/2-pound, round down to the nearest pound.

(2) If the weight fraction of the soldier is 1/2-pound or greater, round up to the next whole pound.

3. Measurements

a. All circumference measurements will be taken three times and recorded to the nearest 1/4-inch (or 0.25). If the measurements are within 1/4-inch of each other, derive a mathematical average to the nearest quarter (1/4) of an inch. If the measurements differ by 1/4-inch or more continue measurements until you obtain three measures within 1/4-inch of each other. Then average the three closest measures.

b. Each set of measurements will be completed sequentially to discourage assumption of repeated measurement readings. For males, complete 1 set of abdomen and neck measurements. NOT three abdomen circumferences followed by three neck circumferences. Continue the process by measuring the abdomen and neck in series until you have three sets of measurements. For females, complete one set of hip, forearm, neck and wrist measurements. NOT 3 hip followed by three forearm etc. continue the process by measuring hip, forearm, neck, and wrist series until you have 3 sets of measurements.

4. Calculations

a. Worksheets for computing body fat are shown in Figures A-1 (males) and A-2 (females). Supporting factor tables are presented in Figures A-3 and A-4. Detailed steps are given on the worksheets.

5. Circumference sites and landmarks for males

a. Abdomen. The soldier being measured will be standing with arms relaxed. The abdominal measurement is taken at a level coinciding with the midpoint of the navel (belly button) with the tape placed so that it is level all the way around the soldier being measured. Record the measurement at the end of a normal expiration. It is important that the soldier does not attempt to hold his abdomen in, thus resulting in a smaller measurement. Also the tape must be kept level across the abdomen and back.

b. Neck. The soldier being measured will be standing, looking straight ahead, chin parallel to the floor. The measurement is taken by placing the tape around the neck at a level just below the larynx (Adam's apple). Do not place the tape measure over the Adam's apple. The tape will be as close to horizontal (the tape line in the front of the neck should be at the same height as the tape line in the back of the neck) as anatomically feasible. In many cases the tape will slant down toward the front of the neck. Therefore, care should be taken so as not to involve the shoulder/neck muscles (trapezius) in the measurement. This is a possibility when a soldier has a short neck.

6. Circumference sites and landmarks for females

a. Neck. This procedure is the same as for males.

b. Forearm. The soldier being measured will be standing with the arm extended away from the body so that the forearm is in plain view of the measurer, with the hand palm up. The soldier should be allowed to choose which arm he/she prefers to be measured. Place the tape around the largest forearm circumference. This will be just below the elbow. To ensure that this is truly the largest circumference, since it is being visually identified, slide the tape along the forearm to find the largest circumference.

c. Wrist. The soldier being measured will stand with the arm extended away from the body so that the wrist is in plain view of the measurer. The tape will be placed around the wrist at a point above the hand just below the lower end of the bones of the forearm.

d. Hip. The soldier taking the measurement will view the person being measured from the side. Place the tape around the hips so that it passes over the greatest protrusion of the gluteal muscles (buttocks) keeping the tape in a horizontal plane (i.e., parallel to the floor). Check front to back and side to side to be sure the tape is level to the floor on all sides before the measurements are recorded. Since the soldier will be wearing gym shorts, the tape can be drawn snugly to minimize the influence of the shorts on the size of the measurement.

BODY FAT CONTENT WORKSHEET *(Male)*

For use of this form, see AR 600-9, the proponent agency is DCSPER

NAME *(Last, First, Middle Initial)*	SSN	RANK	NOTE 1/4" = .25 1/2" = .50 3/4" = .75
HEIGHT *(to nearest 0.25 inch)*	WEIGHT *(to nearest pound)*	AGE	

STEP	FIRST	SECOND	THIRD	AVERAGE *(to nearest 0.25 in.)*
1. Measure abdomen at the level of the navel *(belly button)* to the nearest 0.25 inch *(Repeat 3 times.)*				
2. Measure neck just below level of larynx *(Adam's apple)* to the nearest 0.25 inch. *(Repeat 3 times.)*				
3 Enter the average abdominal measurement to the nearest 0.25 inch.				
4 Enter the average neck measurement to the nearest 0.25 inch				
5 Subtract Step 4 from Step 3 *(Enter result)* to the nearest 0.25 inch				
6 Find result from Line 5 *(the difference between Neck and Abdomen)* in Table B-1 *(Abdomen-Neck Factor)* Enter factor				
7. Find the height in Table B-2 *(Height Factor)* Enter factor				
8 Subtract Step 7 from Step 6 *(Enter result)* This is Soldier's Percent Body Fat				

REMARKS

CHECK ONE

___ Individual is in compliance with Army Standards, ___ is not in compliance with the standards

___ Recommended monthly weight loss is 3-8 lbs

PREPARED BY *(Signature)*	RANK	DATE	APPROVED BY SUPERVISOR *(Printed Name and Signature)*	RANK	DATE

DA FORM 5500-R, DEC 85

FIGURE A-1. Body fat calculation worksheet for males.

BODY FAT CONTENT WORKSHEET *(Female)*

For use of this form, see AR 600-9, the proponent agency is DCSPER

NAME *(Last, First, Middle Initial)*	SSN	RANK	NOTE
HEIGHT *(to nearest 0.25 inch)*	WEIGHT *(to nearest pound)*	AGE	1/4" = .25 1/2" = .50 3/4" = .75

STEP	FIRST	SECOND	THIRD	AVERAGE *(to nearest 0.25 in.)*
1. Find the soldier's weight in Table B-3 *(Weight Factor)*. Enter factor in 11A below				
2. Find soldier's height in Table B-4 *(Height Factor)* Enter factor in 11D below				
3 Measure hips at point where the gluteus muscles *(buttocks)* protrude backward the most. Round off to nearest 0.25 inch. Repeat three times, then average				
4. Measure forearm at its largest point *(with arm horizontal, palm up)* to nearest 0.25 inch. Repeat three times, then average				
5 Measure neck just below level of larynx *(Adam's apple)* to nearest 0.25 inch. Repeat three times and average				
6 Measure wrist between the bones of the hand and forearm to nearest 0.25 inch. Repeat three times, then average				
7 Find average hip measurement in Table B-5 *(Hip Factor)* Enter factor in 11B below				
8 Find average forearm measurement in Table B-6 *(Forearm Factor)* Enter factor in 11E below				
9 Find average neck measurement in Table B-7 *(Neck Factor)* Enter factor in 11F below				
10 Find average wrist measurement in Table B-8 *(Wrist Factor)* Enter factor in 11G below				

11. CALCULATIONS			REMARKS
A Weight factor			
B Hip factor			
C TOTAL *(11A + 11B)*			
D Height factor			
E Forearm factor			
F Neck factor			
G Wrist factor			
H. TOTAL *(11D + E + F + G)*			
I SOLDIER'S PERCENT BODY FAT *(Line 11C—11H)*			

CHECK ONE

___ Individual is in compliance with Army Standards, _____ is not in compliance with the standards

___ Recommended monthly weight loss is 3-8 lbs

PREPARED BY *(Signature)*	RANK	DATE	APPROVED BY SUPERVISOR *(Printed Name and Signature)*	RANK	DATE

DA FORM 5501-R, DEC 85

FIGURE A-2. Body fat calculation worksheet for females.

Table B–1
Male Abdomen and Neck Factor

Difference in inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
5	53.44	55.06	56.61	58.09
6	59.50	60.85	62.16	63.41
7	64.62	65.78	66.91	68.00
8	69.05	70.07	71.07	72.03
9	72.96	73.87	74.76	75.62
10	76.46	77.28	78.08	78.86
11	79.63	80.37	81.10	81.82
12	82.52	83.20	83.87	84.53
13	85.17	85.81	86.43	87.04
14	87.64	88.22	88.80	89.37
15	89.93	90.48	91.02	91.55
16	92.07	92.58	93.09	93.59
17	94.08	94.57	95.05	95.52
18	95.98	96.44	96.89	97.34
19	97.78	98.21	98.64	99.06
20	99.48	99.89	100.30	100.70
21	101.10	101.49	101.88	102.26
22	102.64	103.02	103.39	103.76
23	104.12	104.48	104.83	105.19
24	105.53	105.88	106.22	106.56
25	106.89	107.22	107.55	107.87
26	108.19	108.51	108.82	109.14
27	109.44	109.75	110.05	110.35
28	110.65	110.95	111.24	111.53
29	111.82	112.10	112.39	112.67
30	112.94	113.22	113.49	113.76
31	114.03	114.30	114.56	114.83
32	115.09	115.35	115.60	115.86
33	116.11	116.36	116.61	116.85
34	117.10	117.34	117.58	117.82
35	118.06	118.30	118.53	118.77
36	119.00	119.23	119.46	119.68
37	119.91	120.13	120.35	120.57
38	120.79	121.01	121.23	121.44
39	121.66	121.87	122.08	122.29
40	122.50	122.70	122.91	123.11

Table B–2
Male Height Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
60	75.23	75.35	75.48	75.60
61	75.72	75.84	75.96	76.09
62	76.21	76.33	76.45	76.56
63	76.68	76.80	76.92	77.04
64	77.15	77.27	77.39	77.50
65	77.62	77.73	77.84	77.96
66	78.07	78.18	78.30	78.41
67	78.52	78.63	78.74	78.85
68	78.96	79.07	79.18	79.29
69	79.40	79.50	79.61	79.72
70	79.83	79.93	80.04	80.14
71	80.25	80.35	80.46	80.56
72	80.67	80.77	80.87	80.98
73	81.08	81.18	81.28	81.38
74	81.48	81.58	81.68	81.78
75	81.88	81.98	82.08	82.18
76	82.28	82.38	82.47	82.57
77	82.67	82.77	82.86	82.96
78	83.05	83.15	83.24	83.34
79	83.43	83.53	83.62	83.72
80	83.81	83.90	83.99	84.09
81	84.18	84.27	84.36	84.45
82	84.54	84.64	84.73	84.82
83	84.91	85.00	85.08	85.17
84	85.26	85.35	85.44	85.53

FIGURE A-3. Body fat calculation factor tables for males.

Table B-3
Female Weight Factor

Pounds	0	1	2	3	4	5	6	7	8	9
90	134.08	134.58	135.08	135.55	136.07	136.55	137.03	137.50	137.97	138.44
100	138.90	139.35	139.80	140.25	140.69	141.13	141.56	141.99	142.42	142.84
110	143.26	143.67	144.08	144.49	144.89	145.29	145.69	146.08	146.47	146.86
120	147.24	147.62	147.99	148.37	148.74	149.10	149.47	149.83	150.19	150.54
130	150.90	151.25	151.60	151.94	152.28	152.62	152.96	153.30	153.63	153.96
140	154.29	154.61	154.94	155.26	155.58	155.89	156.21	156.52	156.83	157.14
150	157.44	157.75	158.05	158.35	158.65	158.94	159.24	159.53	159.82	160.11
160	160.40	160.68	160.96	161.25	161.53	161.80	162.08	162.35	162.63	162.90
170	163.17	163.44	163.70	163.97	164.23	164.49	164.75	165.01	165.27	165.53
180	165.78	166.04	166.29	166.54	166.79	167.04	167.28	167.53	167.77	168.02
190	168.26	168.50	168.74	168.97	169.21	169.44	169.68	169.91	170.14	170.37
200	170.60	170.83	171.06	171.28	171.51	171.73	171.95	172.18	172.40	172.62
210	172.83	173.05	173.27	173.48	173.70	173.91	174.12	174.33	174.54	174.75
220	174.96	175.20	175.41	175.61	175.82	176.02	176.22	176.42	176.62	176.82
230	177.03	177.22	177.42	177.62	177.81	178.00	178.20	178.40	178.59	178.78
240	178.97	179.16	179.35	179.54	179.73	179.92	180.10	180.29	180.47	180.66
250	180.84	181.02	181.20	181.39	181.57	181.75	181.92	182.10	182.28	182.46
260	182.63	182.81	182.98	183.16	183.33	183.51	183.68	183.85	184.02	184.19
270	184.36	184.53	184.70	184.87	185.03	185.20	185.37	185.53	185.70	185.86

Table B-4
Female Height Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
55	71.97	72.30	72.62	72.95
56	73.28	73.61	73.93	74.26
57	74.59	74.91	75.24	75.57
58	75.90	76.22	76.55	76.88
59	77.20	77.53	77.86	78.19
60	78.51	78.84	79.17	79.49
61	79.82	80.15	80.48	80.80
62	81.13	81.46	81.78	82.11
63	82.44	82.77	83.09	83.42
64	83.75	84.07	84.40	84.73
65	85.06	85.38	85.71	86.04
66	86.36	86.69	87.02	87.35
67	87.67	88.00	88.33	88.65
68	88.98	89.31	89.64	89.96
69	90.29	90.62	90.94	91.27
70	91.60	91.93	92.25	92.58
71	92.91	93.23	93.56	93.89
72	94.22	94.54	94.87	95.20
73	95.52	95.85	96.18	96.51
74	96.83	97.16	97.49	97.81
75	98.14	98.47	98.80	99.12
76	99.45	99.78	100.10	100.43
77	100.76	101.09	101.41	101.74
78	102.07	102.39	102.72	103.05
79	103.38	103.70	104.03	104.36
80	104.68	105.01	105.34	105.67

Table B-5
Female Hip Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
30	13.19	13.30	13.41	13.52
31	13.63	13.74	13.85	13.96
32	14.07	14.18	14.29	14.40
33	14.51	14.62	14.73	14.84
34	14.95	15.06	15.17	15.28
35	15.39	15.50	15.61	15.72
36	15.83	15.94	16.05	16.15
37	16.26	16.37	16.48	16.59
38	16.70	16.81	16.92	17.03
39	17.14	17.25	17.36	17.47
40	17.58	17.69	17.80	17.91
41	18.02	18.13	18.24	18.35
42	18.46	18.57	18.68	18.79
43	18.90	19.01	19.12	19.23
44	19.34	19.45	19.56	19.67
45	19.78	19.89	20.00	20.11
46	20.22	20.33	20.44	20.55
47	20.66	20.77	20.88	20.99
48	21.10	21.21	21.32	21.43
49	21.54	21.65	21.76	21.87
50	21.98	22.09	22.20	22.31

Table B-6
Female Forearm Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
5	19.96	20.96	21.96	22.96
6	23.96	24.96	25.96	26.96
7	27.96	28.96	29.96	30.97
8	31.97	32.97	33.97	34.97
9	35.97	36.97	37.97	38.97
10	39.97	40.97	41.97	42.97
11	43.96	44.96	45.96	46.96
12	47.96	48.96	49.96	50.96
13	51.96	52.96	53.96	54.96
14	55.96	56.95	57.95	58.95
15	59.95	60.95	61.95	62.95

Table B-7
Female Neck Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
5	6.77	7.11	7.45	7.79
6	8.12	8.46	8.80	9.14
7	9.48	9.82	10.16	10.49
8	10.83	11.17	11.51	11.85
9	12.19	12.53	12.86	13.20
10	13.54	13.88	14.22	14.56
11	14.90	15.23	15.57	15.91
12	16.25	16.59	16.93	17.26
13	17.60	17.94	18.28	18.62
14	18.96	19.30	19.63	19.97
15	20.31	20.65	20.99	21.33

Table B-8
Female Wrist Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
5	2.54	2.67	2.80	2.93
6	3.05	3.18	3.31	3.43
7	3.56	3.69	3.82	3.94
8	4.07	4.20	4.33	4.45
9	4.58	4.71	4.83	4.96
10	5.09	5.22	5.34	5.47
11	5.60	5.72	5.85	5.98
12	6.11	6.23	6.36	6.49
13	6.62	6.74	6.87	7.00
14	7.12	7.25	7.38	7.51
15	7.63	7.76	7.89	8.01

FIGURE A-4. Body fat calculation factor tables for females.

APPENDIX - B

WORKSHEET FOR MALE BODY FAT CALCULATION

ABDOMEN2 CIRCUMFERENCE - NECK CIRCUMFERENCE

INCHES	+0	+1/4	+1/2	+3/4
9	-7.98	-7.07	-6.18	-5.32
10	-4.48	-3.66	-2.86	-2.08
11	-1.31	-0.57	0.16	0.88
12	1.58	2.26	2.93	3.59
13	4.23	4.87	5.49	6.10
14	6.70	7.28	7.86	8.43
15	8.99	9.54	10.08	10.61
16	11.13	11.64	12.15	12.65
17	13.14	13.63	14.11	14.58
18	15.04	15.50	15.95	16.40
19	16.84	17.27	17.70	18.12
20	18.54	18.95	19.36	19.76
21	20.16	20.55	20.94	21.32
22	21.70	22.08	22.45	22.82
23	23.18	23.54	23.89	24.25
24	24.59	24.94	25.28	25.62
25	25.95	26.28	26.61	26.93
26	27.25	27.57	27.88	28.20
27	28.50	28.81	29.11	29.41
28	29.71	30.01	30.30	30.59
29	30.88	31.16	31.45	31.73
30	32.00	32.28	32.55	32.82
31	33.09	33.36	33.62	33.89
32	34.15	34.41	34.66	34.92
33	35.17	35.42	35.67	35.91
34	36.16	36.40	36.64	36.88
35	37.12	37.36	37.59	37.83
36	38.06	38.29	38.52	38.74
37	38.97	39.19	39.41	39.63
38	39.85	40.07	40.29	40.50
39	40.72	40.93	41.14	41.35
40	41.56	41.76	41.97	42.17

HEIGHT

INCHES	+0	+1/4	+1/2	+3/4
60	8.86	8.74	8.62	8.49
61	8.37	8.25	8.13	8.01
62	7.88	7.76	7.65	7.53
63	7.41	7.29	7.17	7.05
64	6.94	6.82	6.71	6.59
65	6.48	6.36	6.25	6.13
66	6.02	5.91	5.79	5.68
67	5.57	5.46	5.35	5.24
68	5.13	5.02	4.91	4.80
69	4.69	4.59	4.48	4.37
70	4.26	4.16	4.05	3.95
71	3.84	3.74	3.63	3.53
72	3.42	3.32	3.22	3.12
73	3.01	2.91	2.81	2.71
74	2.61	2.51	2.41	2.31
75	2.21	2.11	2.01	1.91
76	1.81	1.71	1.62	1.52
77	1.42	1.33	1.23	1.13
78	1.04	0.94	0.85	0.75
79	0.66	0.56	0.47	0.38
80	0.28	0.19	0.10	0.00

NAME: ______________
DATE: ______________
AGE: ______________
SEX: ______________

WEIGHT: ______________
HEIGHT: ______________

ABDOMEN2: ______________
NECK: ______________
ABDOMEN2-NECK: ______________

CALCULATIONS:

ADD THE FOLLOWING:
ABDOMEN-NECK FACTOR: __________
HEIGHT FACTOR:+__________

PERCENT BODYFAT = __________

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